Engineering Note
for
E906 Detector Assembly

PROJECT: E906

TITLE: Station 3 and 4 Hodoscope Installation and Hanging

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ABSTRACT: This document describes the hardware used to install and suspend Station 3 and 4 hodoscopes in E906.

OVERVIEW:
There are six hodoscope planes used in Station 3 & 4 of E906. The components used vary only slightly. The general description below will be followed by analysis of each detector and any differences detailed. These detectors are designed to roll perpendicular to the beam axis for service. The details of service and rolling the detectors beyond the existing structure will be detailed in another engineering note. Dimensions in all drawings are in inches.

DESIGN:
The construction details of the six hodoscopes have been addressed in other engineering notes. This note begins with a vertically oriented chamber. (See Figure 1)

The two hoist rings used to lift the hodoscope vertical are replaced by rod ends using nuts on both sides of the detector frame steel corner plates to lock orientation.

A turnbuckle is connected to the rod end using a bronze bushing.

The turnbuckle top is connected to a machined steel adapter for the Ronstan Marine trolleys.

The Ronstan Marine trolleys are connected to the adapter with two 3/8" grade 5 bolts, nuts and washers.

The Ronstan Marine I beam track is connected to the 5x2 steel box beam using 5/16" flat head bolts on 10cm centers, passing thru the box beam to a ½" thick steel nut plate located inside the box beam.

The box beam is to be lifted by two 2" square rigging pads welded to the top surface of the box beam. (shown with dimensions in Figure 3) The rigging pads are tapped to accept ½-13 hoist rings.

The chamber/ box beam assembly is lowered into place onto the Station 3 & 4 support structure so that the flat steel weldments on each end contact the top surface of the drop plate. The assembly is held in place via gravity. A clearance hole in the box beam is provided to fix the position on the drop with a ½-13 bolt. The details of the Station 3 & 4 Support Structure and drop connections are covered in other engineering notes.

A Ronstan Track Pin Stop (McMaster Carr part 9484T13) is positioned in the track using manufacturer supplied holes on 5cm centers. A pin stop is placed on each side of the detector preventing side to side movement of the trolleys. If access to that pin location is difficult, a spacer will be used.

If disassembly of the detector is required, the box beam and hanging hardware will be removed and the hoist rings reinstalled on the steel plates in order to lay the chamber horizontal.

ANALYSIS:
The components for each detector will be described and analyzed as follows:

Hodoscope 3x

From previous engineering note, the Station 3X hodoscope assembly weighs 500lbs. There is only one instance of this detector.

Rod End:
The rod ends installed on the 3X detector steel plate are ½-13 rod ends purchased form McMaster Carr (part 2440K250). They are constructed of 4140 steel as per ASTM A193-B7 with a tensile strength of 125ksi, yield strength of 105ksi, and allowable stress of 26ksi. The nuts used to lock the orientation are Grade 5 nuts (McMaster Carr part 95462A033). The tensile stress area for a ½-13 fastener is 0.128 in^2) The 250lb load on the rod end creates a tensile stress of

Stress on one rod end = 250lbs / 0.128in^2 = 1953psi.
This load is within limits

Turnbuckle:
The 3X hodoscope uses a Forged Galvanized Steel turnbuckle with a load rating of 2200lbs and rated as per ASTM F1145-05 Type 1, Grade 1. The parts were purchased from McMaster Carr (part 3001T54). The 7/16 diameter pin was adapted to the ½ rod end using a bronze bushing (McMaster Carr part 6391k173). The specifications for this part are acceptable for the 250lb loads expected.

Trolley Adapter:
The trolley adapter is machined from 1018 steel with a yield strength of 53.7ksi. The allowable shear stress for tearout is 0.4Fy = 21.48ksi.
The trolley adapter hole for the turnbuckle is subject to tear out stress.

Hole tearout analysis:
(SEE FIGURE 4)
Load on 0.469” hole is 250 lbs (half the chamber weight)
Effective Cross Sectional Area:
Area = 2(0.257)(0.5)
= 0.257 in^2
Shear on hole = 250lbs / 0.257in^2 = 973 psi
This calculation shows the fabricated part is within allowed limits.

The Trolley Adapter is connected to the trolley using two 3/8-18 grade 5 bolts (McMaster Carr part 92865A622, nuts (McMaster Carr part 95462A031) and washers (94744A265). The tensile strength (Fu) for a grade 5 fastener is 120ksi and a yield strength (Fy) of 92ksi. Using table I-B and I-C from the AISC AWS 9th edition, the allowable ensile stress for a grade 5 fastener is 0.33Fu = 39.6ksi and a allowable shear stress of 0.17Fu =

20.4ksi. Each bolt sees a 125lb load in tension. The tensile stress area of these bolts is 0.0774 in^2

Bolt stress = 125lbs / 0.0774in^2 = 1615psi.
This is an acceptable load for a grade 5 fastener.

Trolleys:
The Ronstan Trolleys (part RC63201, McMaster Carr part 9484T732) are constructed of 316 stainless steel; a manufacturer specified 1430lbs weight limit. They travel along an I-beam shaped track on stainless steel roller bearings. The 250lb load per cart is within manufacturer specifications.

Ronstan Track:
The Ronstan 32 series track (part RC6320, McMaster Carr part 9484T23) is constructed of marine grade anodized aluminum. The track is provided in 1m or 3m sections. The box beam length requires one 3m section and one shortened 1m section. The track is manufactured with countersunk holes every 10cm for the placement of a 5/16" SHCS flat head fastener. The fastener used (McMaster Carr part 91253A591) manufactured as per ASTM F835 is a flat head SHCS. These fasteners have a minimum tensile strength of 144ksi . Allowable stress is not easily found for flat head SHCS non-structural fasteners . Using a simple stress case 1 from the Machinery's Handbook, the tensile strength is multiplied by the stress area (0.0524in^2) and then divided by a safety factor of 2. This results in a allowable stress of 3773lbs per 5/16" fastener.

The fastener passes thru the 5x2" box beam 1/4" wall into a ½" thick nut plate on the inside of the box beam. The nut plate is composed of A36 steel. The shortest piece of track has 7 fasteners into the nut plate. The 5/16"-18 screws are subject to tensile stress. Half the chamber load on a short piece of track is 250lbs. The load on a single fastener on a short piece of track is 35.7lbs.The tensile stress area for a 5/16-18 fastener is 0.0524in^2. The tensile stress on one fastener is 682psi. This is an acceptable load for this fastener using an allowable stress as described in the previous paragraph.

Box Beam:
The 5x2" box beam is constructed of A36 carbon steel with ¼ wall thickness. The detector stress on the beam reaches a maximum of 2193psi between the two trolleys (see figure 5). The maximum deflection from the detector load is 0.080" at the center of the beam (see figure 6). These numbers are well under the material specifications and tolerable to experimental requirements.

The two rigging pads are welded to the top surface of the box beam. The weld is a 3/16" fillet weld (0.1326" throat) 2" long on both sides for an effective throat area of 0.530in^2. The allowable shear strength for 60XX filler material is = (0.30) (60ksi) =18ksi. This is well above the load per pad of 250lbs / 0.530in^2 = 471psi

Hoist Rings:

The ½-13 hoist rings used to lift the 80/20 framed chamber vertical are used to lift the assembly and place it on the I-beam frame. Each hoist ring supports approximately 250-lbs. The area of a ½-13 bolt, based on a minor diameter of 0.4041-in^2,bolt stress area is

0.128-in^2 and the resulting shear stress in each eyebolt is 250/0.128 = 1953psi. We have identified swivel eyebolts made from forged alloy steel type AISA-SAE 4140 (American Drill Bushing, part number 33515) with a minimum tensile strength of 180ksi. These bolts are certified for a work load limit of 2500-lbs with a pivot range of 180 degrees and a swivel range of 360 degrees and are suitable for this application.

Hodoscope 4Y

From a previous engineering note, the Station 4Y hodoscope assembly weighs 330lbs. There are four (4) instances of this detector in E906.

Differences:
The station 4Y's (and 4X) use a different size turnbuckle from the 3X hodoscope. The bushing and the Trolley Adapter are slightly different to accommodate this size change.

Rod End:
The rod ends installed on the 4Y detector steel plate are a ½-13 rod end purchased form McMaster Carr (part 2440K250 They are constructed of 4140 steel as per ASTM A193-B7 with a tensile strength of 125ksi, yield strength of 105ksi, and allowable stress of 26ksi. The nuts used to lock the orientation are Grade 5 nuts (McMaster Carr part 95462A033. The tensile stress area for a ½-13 fastener is 0.128 in^2) The 165lb load on the rod end creates a tensile stress of

Stress on one rod end = 165lbs / 0.128in^2 = 1289psi.
This load is within limits

Turnbuckle:
The 4Y hodoscope uses a Forged Galvanized Steel turnbuckle with a load rating of 1200lbs and rated as per ASTM F1145-05 Type 1, Grade 1. The parts were purchased from McMaster Carr (part 3001T53). The 5/16 diameter pin was adapted to the ½ rod end using a bronze bushing (McMaster Carr part 6391k405). The specifications for this part are acceptable for the 165lb load expected.

Trolley Adapter:
The trolley adapter is machined from 1018 steel with a yield strength of 53.7ksi. The allowable stress for tearout is 0.4Fy = 21.48ksi.
The trolley adapter hole for the turnbuckle is subject to tear out stress.

Hole tearout analysis:
(SEE FIGURE 8)
Load on 0.303" hole is 165 lbs (half he chamber weight)
Effective Cross Sectional Area:
Area = 2(0.303)(0.5)
= 0.303 in^2
Shear on hole = 165lbs / 0.303in^2 = 545 psi

The Trolley Adapter is connected to the trolley using two 3/8-18 grade 5 bolts (McMaster Carr part 92865A622, nuts (McMaster Carr part 95462A031) and washers (94744A265). Each bolt sees a 82.5lb pound load in tension. The tensile stress area of these bolts is 0.0774 in^2.
tensile stress of single bolt = 82.5lb / 0.0774 = 1066psi.
This is an acceptable load for a grade 5 fastener.

Trolleys:
The Ronstan Trolleys (part RC63201, McMaster Carr part 9484T732) are constructed of 316 stainless steel; manufacturer specified 1430lbs weight limit. They travel along an I-beam shaped track on stainless roller bearings. The 165lb load per cart is within manufacturer specifications.

Ronstan Track:
The Ronstan 32 series track (part RC6320, McMaster Carr part 9484T23) is constructed of marine grade anodized aluminum. The track is provided in 1m or 3m sections. The box beam length requires one 3m section and one shortened 1m section. The track is manufactured with countersunk holes every 10cm for the placement of a 5/16" flat head fastener (McMaster Carr part 91253A591) as per ASTM F835 These fasteners have a minimum tensile strength of 144ksi. Allowable stress is not easily found for non-structural fasteners. Using a simple stress case 1 from the Machinery's Handbook, the tensile strength is multiplied by the stress area (0.0524in^2) and then divided by a safety factor of 2. This results in a load limit of 3773lbs per 5/16" fastener.

The fastener passes thru the 5x2" box beam 0.25" wall into a ½" thick nut plate on the inside of the box beam. The nut plate is composed of A36 steel. The shortest piece of track has 7 fasteners into the nut plate. The5/16"-18 screws are subject to tensile stress. Half the chamber load on a short piece of track is 165lbs. The tensile stress area for a 5/16-18 fastener is 0.0524in^2.

The tensile stress on one fastener = 23.6lb / 0.0524in^2 = 450psi.
This is an acceptable load for this fastener as described in the previous paragraph.

Box Beam:
The 5x2" box beam is constructed of A36 carbon steel with ¼ wall thickness. The detector stress on the beam reaches a maximum of 1143psi between the two trolleys (see figure 9). The maximum deflection from the detector load is 0.042" at the center of the beam (see figure 10). These numbers are well under the material specifications and tolerable to experimental requirements

The two rigging pads are welded to the top surface of the box beam. The weld is a 3/16" fillet weld (0.1326" throat) 2" long on both sides for an effective throat area of 0.530in^2. The allowable shear strength for 60XX filler material is = (0.30) (60ksi) =18ksi. This is well above the shear load per weld = 165lbs / 0.53in^2 = 311psi.

Hoist Rings: The ½-13 hoist rings used to lift the 80/20 framed chamber vertical are used to lift the assembly and place it on the I-beam frame. Each hoist ring supports approximately 165-lbs. The area of a ½-13 bolt, based on a minor diameter of 0.4041-

in^2, with a bolt stress area of0.128-in^2 and the resulting shear stress in each eyebolt is 165lbs / 0.128in^2 = 1289psi. We have identified swivel eyebolts made from forged alloy steel type AISA-SAE 4140 (American Drill Bushing, part number 33515) with a minimum tensile strength of 180ksi, which is well in excess of the actual values stated above. These hoist rings are certified for a work load limit of 2500-lbs with a pivot range of 180 degrees and a swivel range of 360 degrees and are suitable for this application.

Hodoscope 4X

From a previous engineering note, a Station 4X hodoscope assembly weighs 400lbs. The 4X detector has two instances of this design mounted side by side on the same box beam. Each detector half is suspended from a pair of trolleys.

Rod End:
The rod ends installed on the 4X detector steel plate are a ½-13 rod end purchased form McMaster Carr (part 2440K250). They are constructed of 4140 steel as per ASTM A193-B7 with a tensile strength of 125ksi, yield strength of 105ksi, and allowable stress of 26ksi. The nuts used to lock the orientation are Grade 5 nuts (McMaster Carr part 95462A033).The tensile stress area for a ½-13 fastener is 0.128 in^2) The 200lb load on the rod end creates a tensile stress of

Stress on one rod end = 200lbs / 0.128in^2 = 1563psi.
This load is within limits

Turnbuckle:
The 4X hodoscope uses a Forged Galvanized Steel turnbuckle with a load rating of 1200lbs and rated as per ASTM F1145-05 Type 1, Grade 1. The parts were purchased from McMaster Carr (part 3001T53). The 5/16” diameter pin was adapted to the ½ rod end using a bronze bushing (McMaster Carr part 6391k405). The specifications for this part are acceptable for the 200lb load expected.

Trolley Adapter:
The trolley adapter is machined from 1018 steel with a yield strength of 53.7ksi. The allowable stress for tearout is 0.4Fy = 21.48ksi.
The trolley adapter hole for the turnbuckle is subject to tear out stress.

Hole tearout analysis:
(SEE FIGURE 8)
Load on 0.303” hole is 200 lbs (half the chamber weight)
Effective Cross Sectional Area:
Area = 2(0.303)(0.5)
= 0.303 in^2
Shear on hole = 200lbs / 0.303in^2 = 660 psi

The Trolley Adapter is connected to the trolley using two 3/8-18 grade 5 bolts (McMaster Carr part 92865A622, nuts (McMaster Carr part 95462A031) and washers (94744A265). Each bolt sees a 100lb load in tension. The tensile stress area of these bolts is 0.0774 in^2 for a tensile stress of 1292 psi. This is an acceptable load for a grade 5 fastener.

Trolleys:
The Ronstan Trolleys (part RC63201, McMaster Carr part 9484T732) are constructed of 316 stainless steel; manufacturer specified 1430lbs weight limit. They travel along an I-beam shaped track on stainless roller bearings. The 200lb load per cart is within manufacturer specifications.

Ronstan Track:
The Ronstan 32 series track (part RC6320, McMaster Carr part 9484T23) is constructed of marine grade anodized aluminum. The track is provided in 1m or 3m sections. The box beam length requires one 3m section and one shortened 1m section. The track is manufactured with countersunk holes every 10cm for the placement of a 5/16" flat head fastener (McMaster Carr part 91253A591) as per ASTM F835, is a flat head SHCS. These fasteners have a minimum tensile strength of 144ksi . Allowable stress is not easily found for non-structural fasteners. Using a simple stress case 1 from the Machinery's Handbook, the tensile strength is multiplied by the stress area (0.0524in^2) and then divided by a safety factor of 2. This results in a load limit of 3744lbs per 5/16" fastener.

The fastener passes thru the 5x2" box beam 0.25" wall into a ½" thick nut plate on the inside of the box beam. The nut plate is composed of A36 steel. The shortest piece of track has 7 fasteners into the nut plate. The5/16"-18 screws are subject to tensile stress. Half the chamber load on the short piece of track is 200lbs. The tensile stress area for a 5/16-18 fastener is 0.0524in^2. The tensile stress on one fastener is 545psi. This is an acceptable load for this fastener as described in the previous paragraph. The center section of the track has two trolleys close together, to double the load on a single fastener would be 1090psi. This is still an acceptable load for this connection.

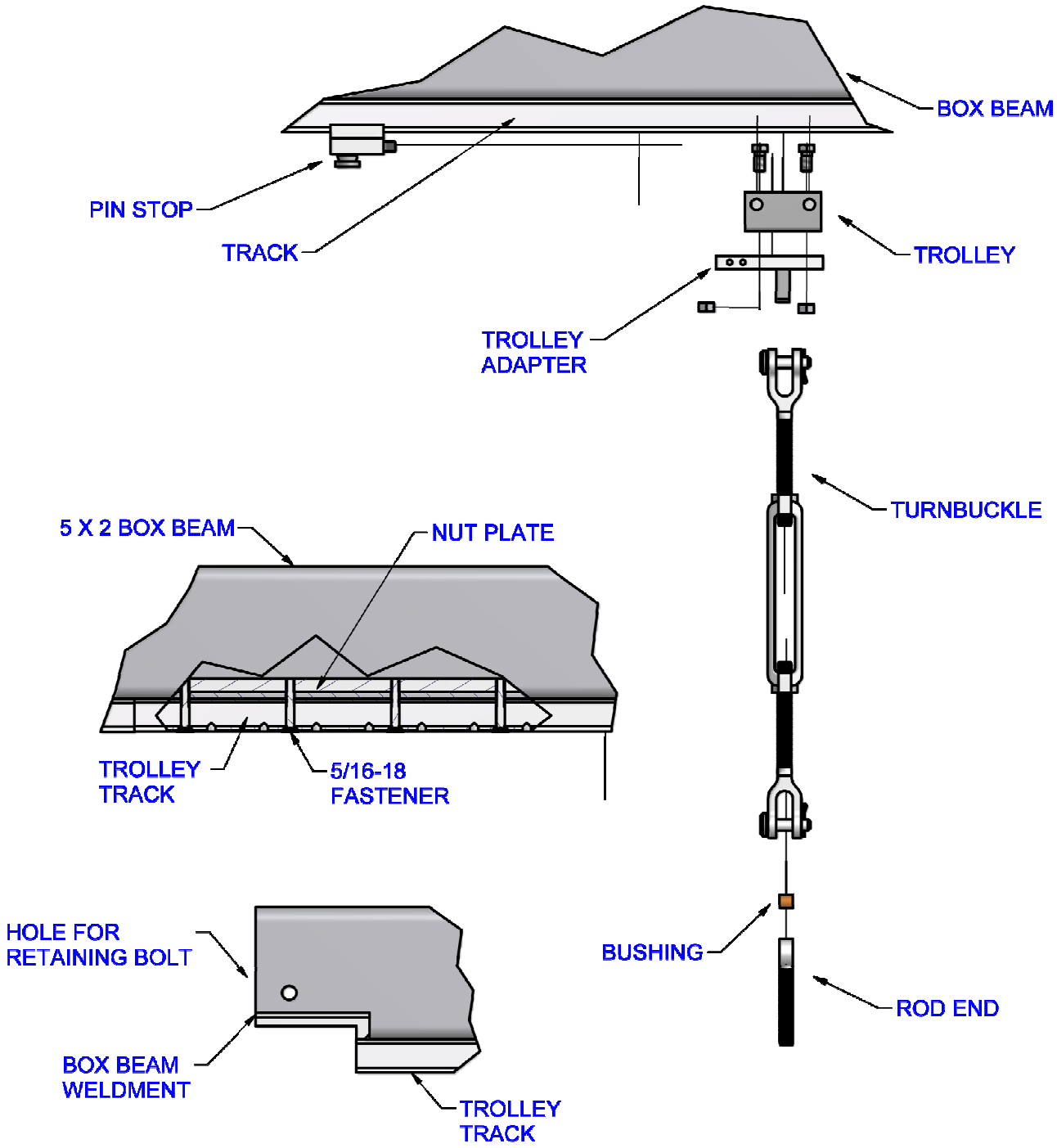
Box Beam:
The 5x2" box beam is constructed of A36 carbon steel with ¼ wall thickness. The detector stress on the beam reaches a maximum of 5162psi between the two trolleys (see figure 13). The maximum deflection from the detector load is 0.146" at the center of the beam (see figure 14). These numbers are well under the material specifications and tolerable to experimental requirements

The two rigging pads are welded to the top surface of the box beam. The weld is a 3/16" fillet weld (0.1326" throat) 2" long on both sides for an effective throat area of 0.530in^2. The allowable shear strength for 60XX filler material is = (0.30)(60ksi) =18ksi. This is well above the shear stress of 400lb / 0.530in^2 = 754psi load per weld.

Hoist Rings:

The ½-13 hoist rings used to lift the 80/20 framed chamber vertical are used to lift the assembly and place it on the I-beam frame. Each hoist ring supports approximately 400-lbs. The area of a ½-13 bolt, based on a minor diameter of 0.4041-in^2, with a bolt stress area of 0.128-in^2 and the resulting shear stress in each eyebolt is 400lbs/0.128in^2 =

3125psi. We have identified swivel eyebolts made from forged alloy steel type AISA-SAE 4140 (American Drill Bushing, part number 33515) with a minimum tensile strength of 180ksi, which is well in excess of the actual values stated above. These bolts are certified for a work load limit of 2500-lbs with a pivot range of 180 degrees and a swivel range of 360 degrees and are suitable for this application.



BOX BEAM DETAILS

Figure 1

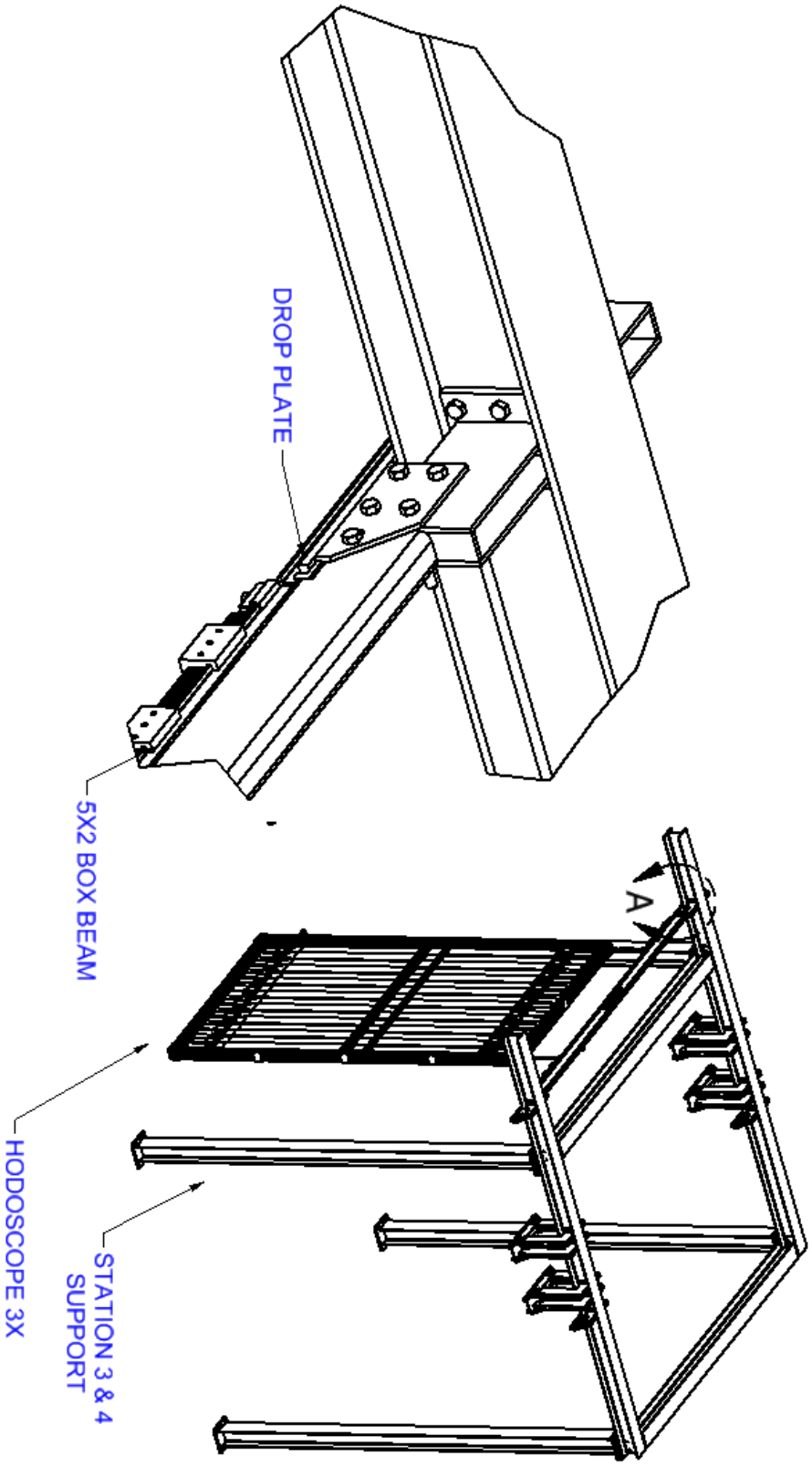


Figure 2

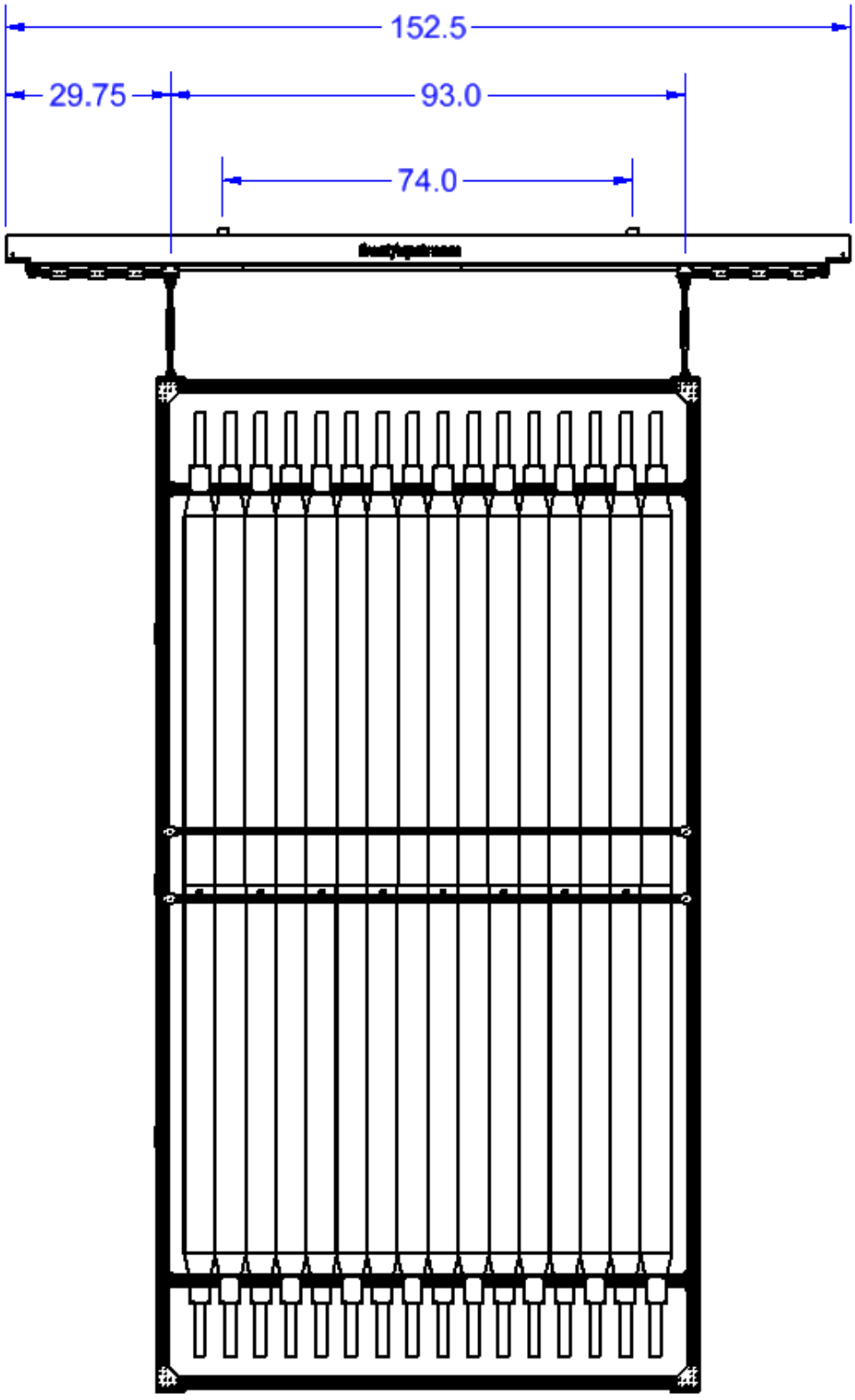


Figure 3

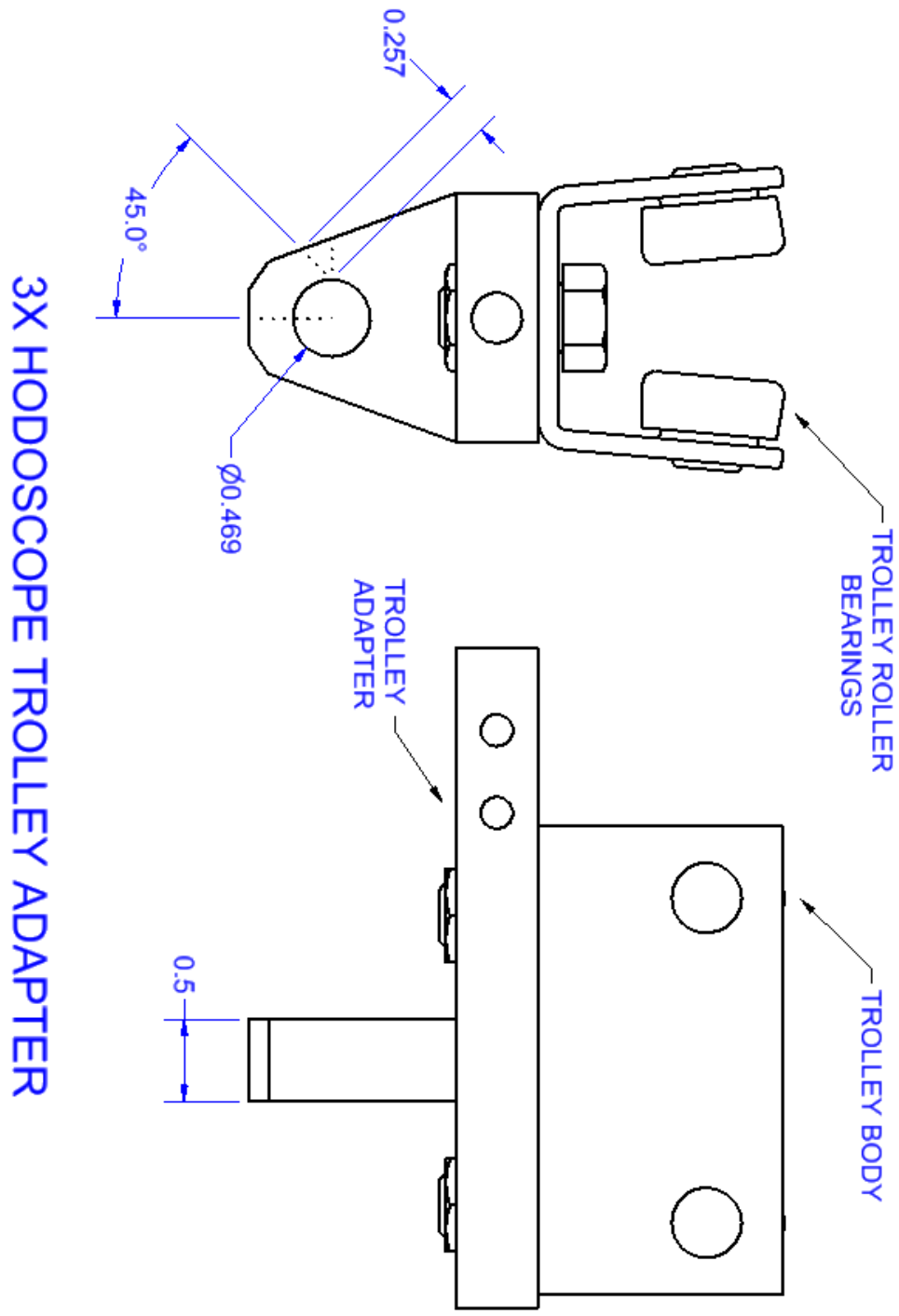

3X HODOSCOPE TROLLEY ADAPTER
0.257
45.0°
Ø0.469
TROLLEY ROLLER BEARINGS
TROLLEY ADAPTER
TROLLEY BODY
0.5

Figure 4

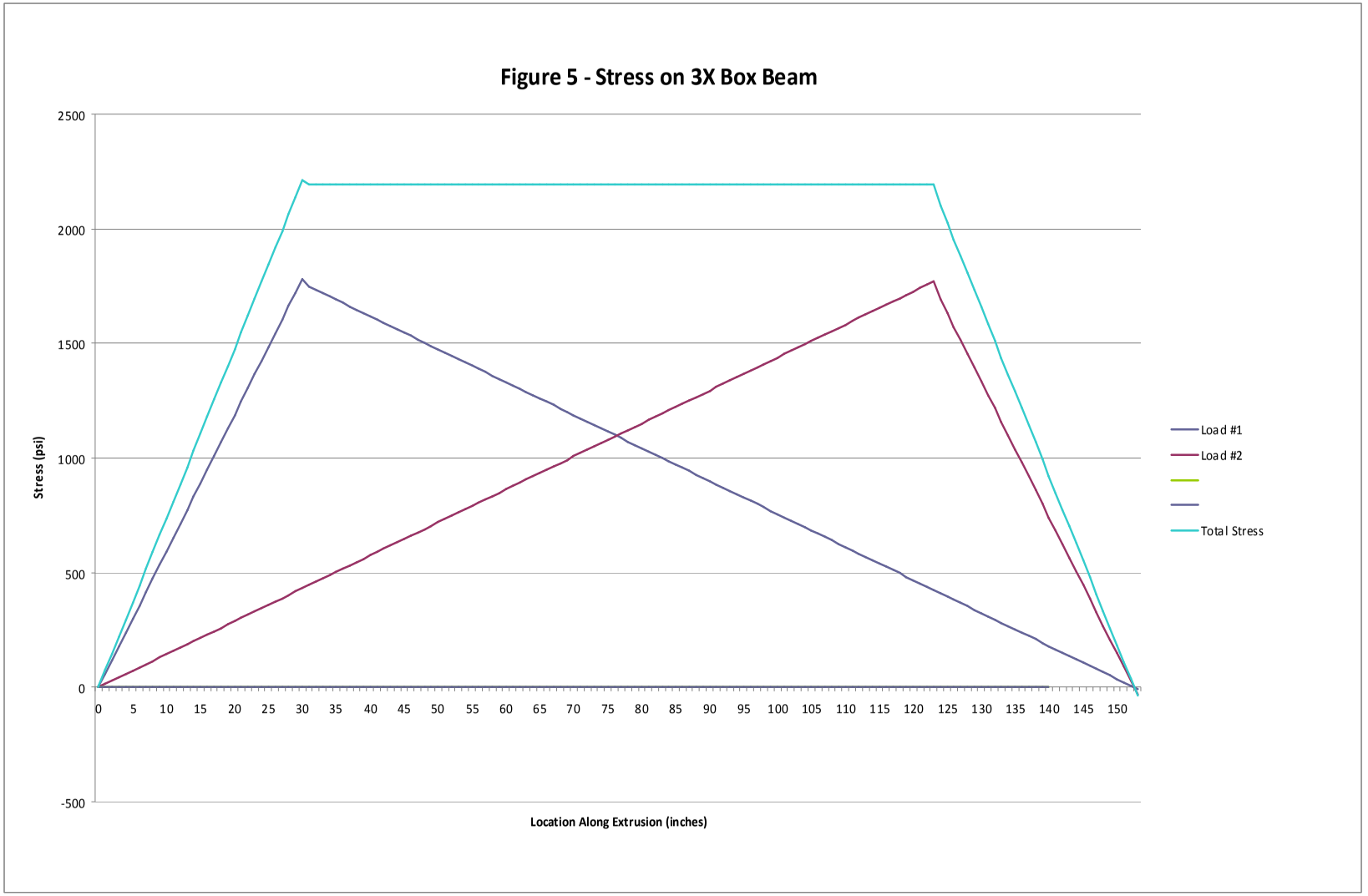


Figure 5 - Stress on 3X Box Beam
2500
2000
1500
1000
500
0
-500
Stress (psi)
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150
Location Along Extrusion (inches)
Load #1
Load #2
Total Stress

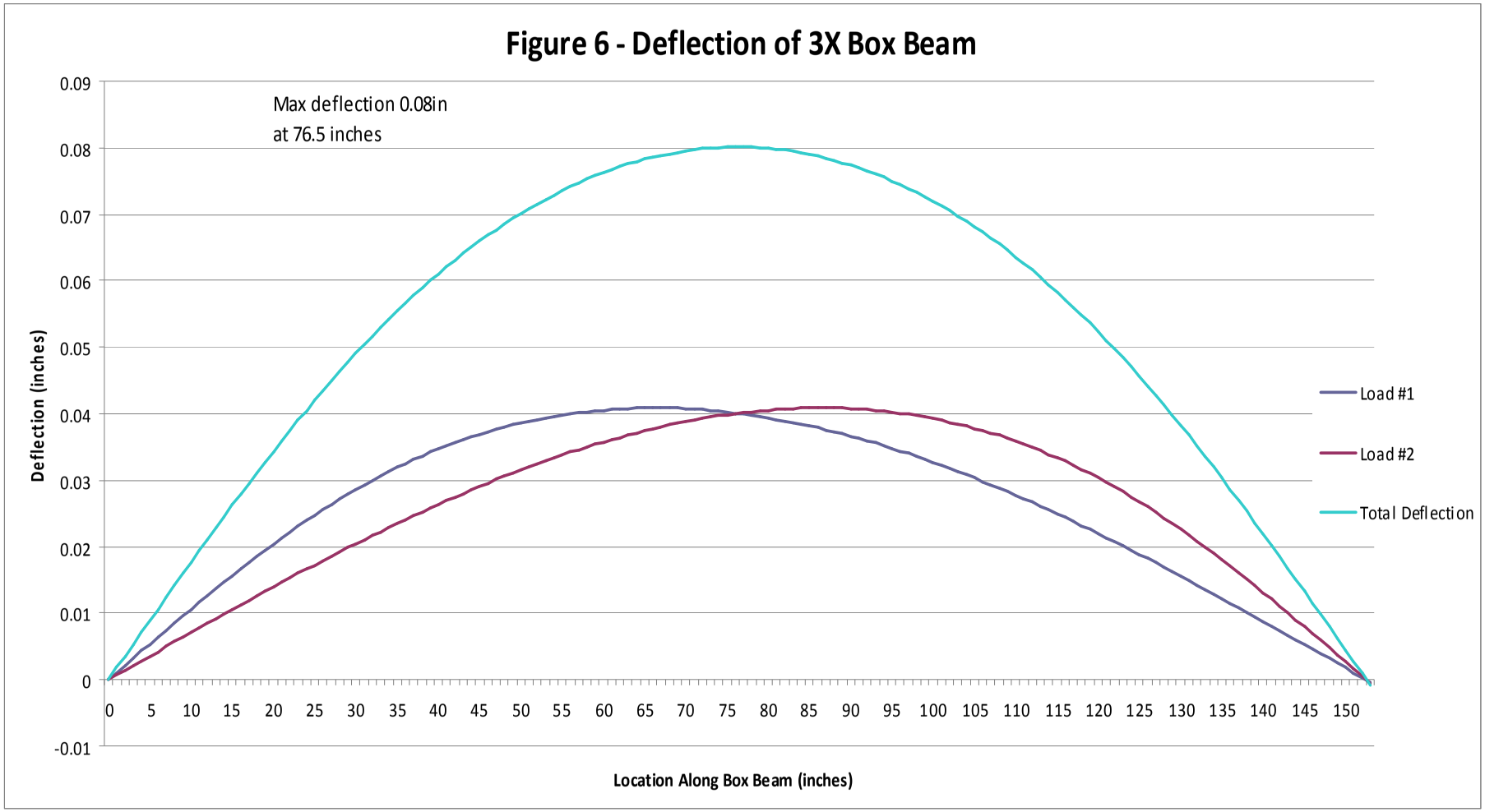


Figure 6 - Deflection of 3X Box Beam
Max deflection 0.08in
at 76.5 inches
Deflection (inches)
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150
Location Along Box Beam (inches)
Load #1
Load #2
Total Deflection

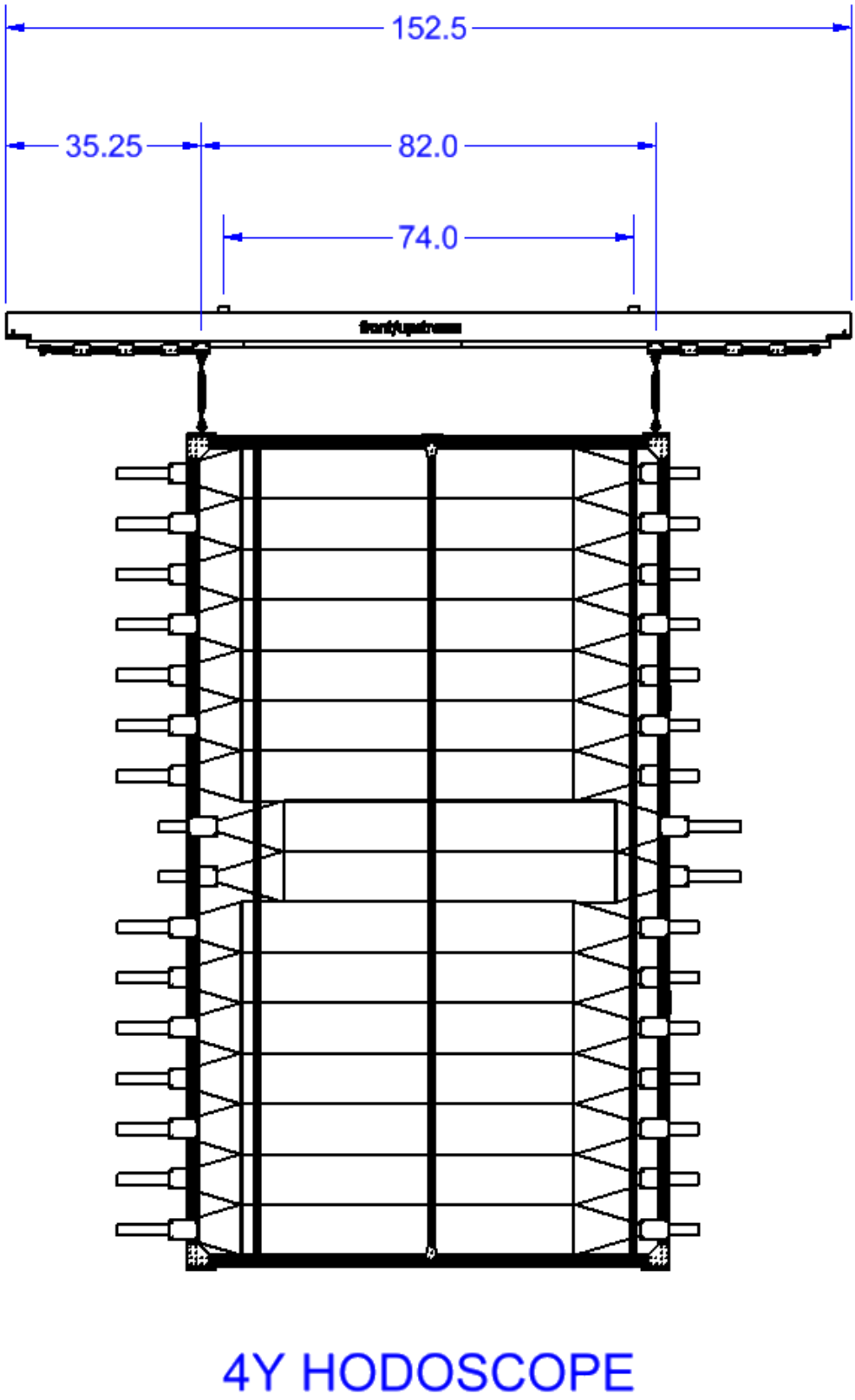
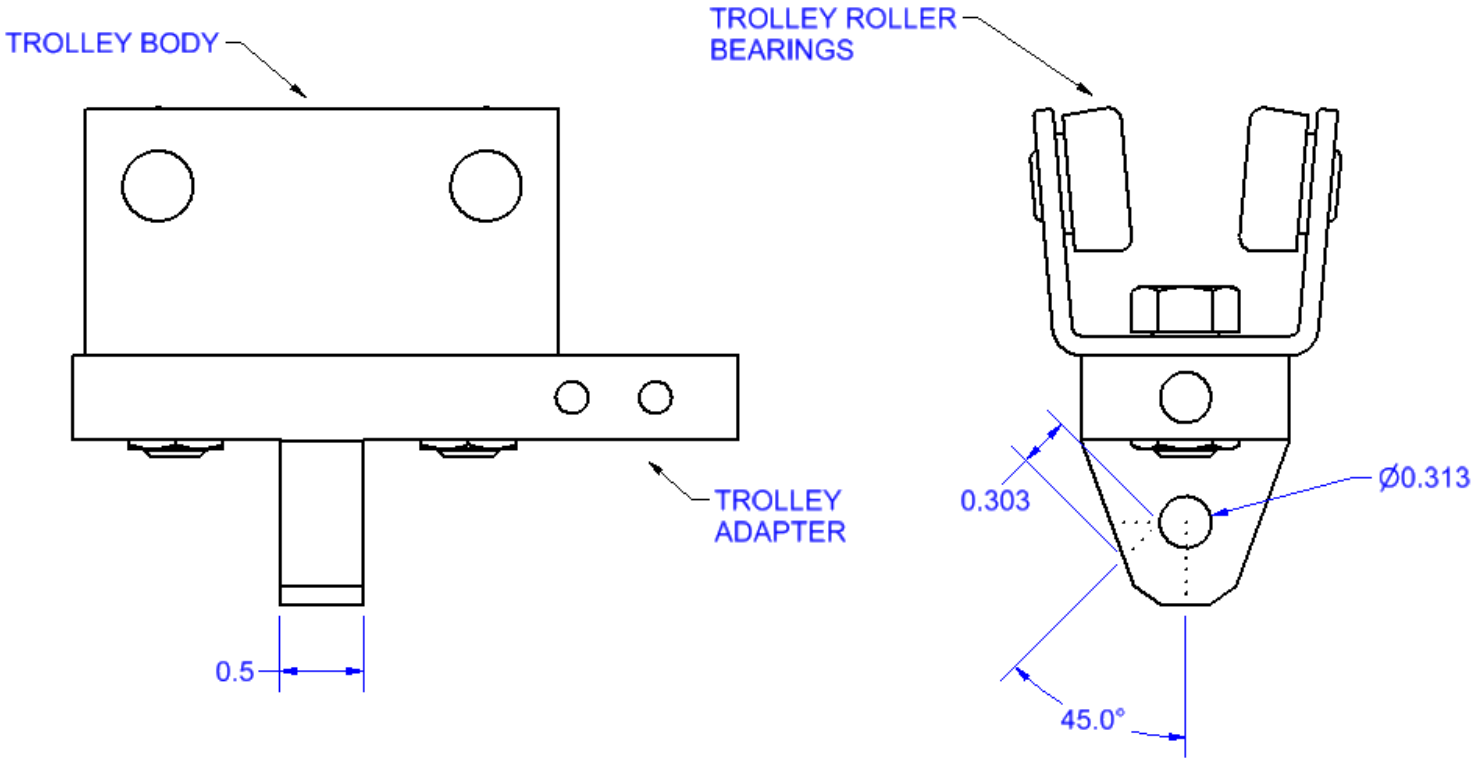


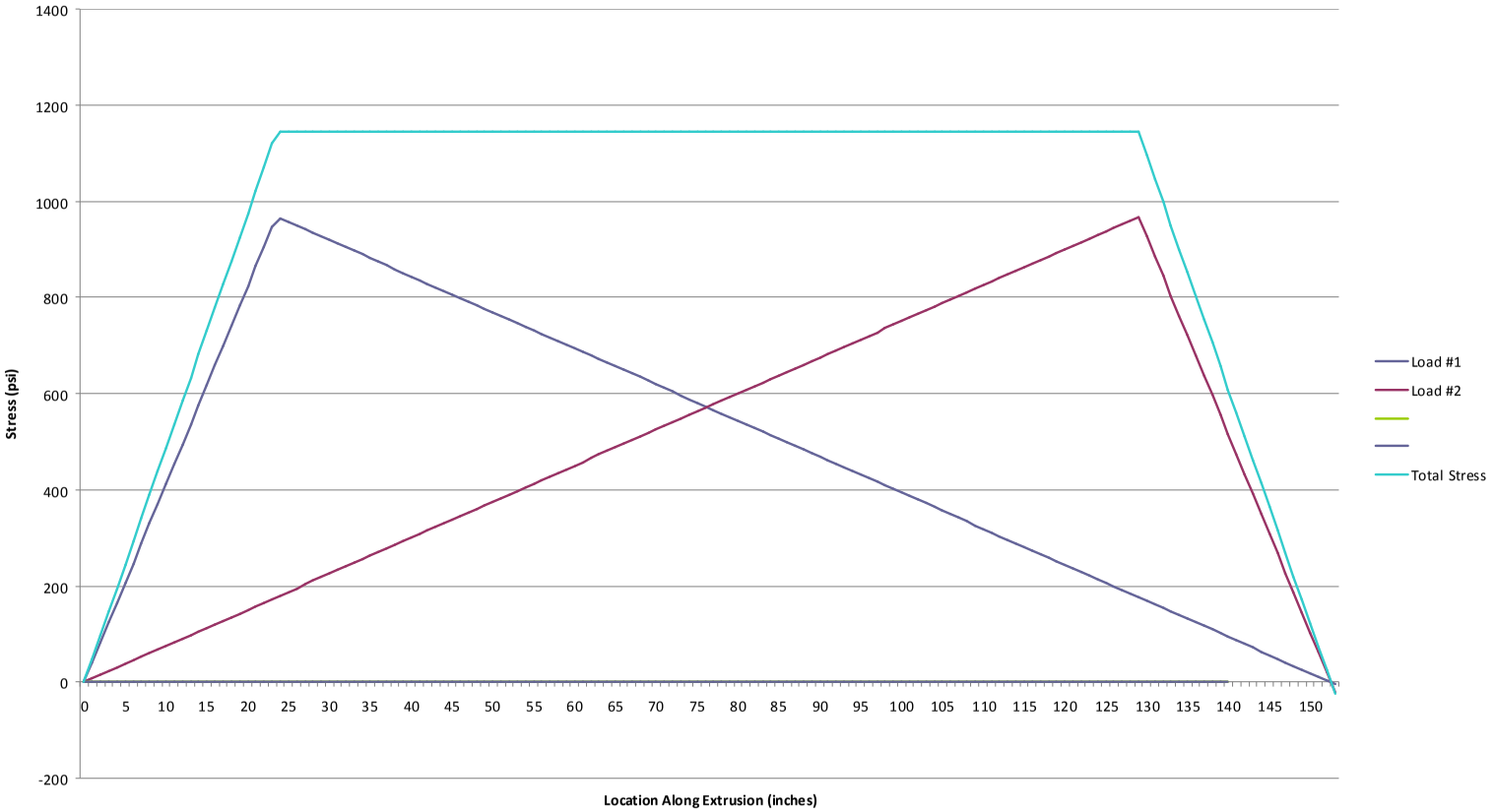
Figure 7



4X AND 4Y HODOSCOPE TROLLEY ADAPTER

Figure 8

Figure 9 - Stress on 4Y Box Beam



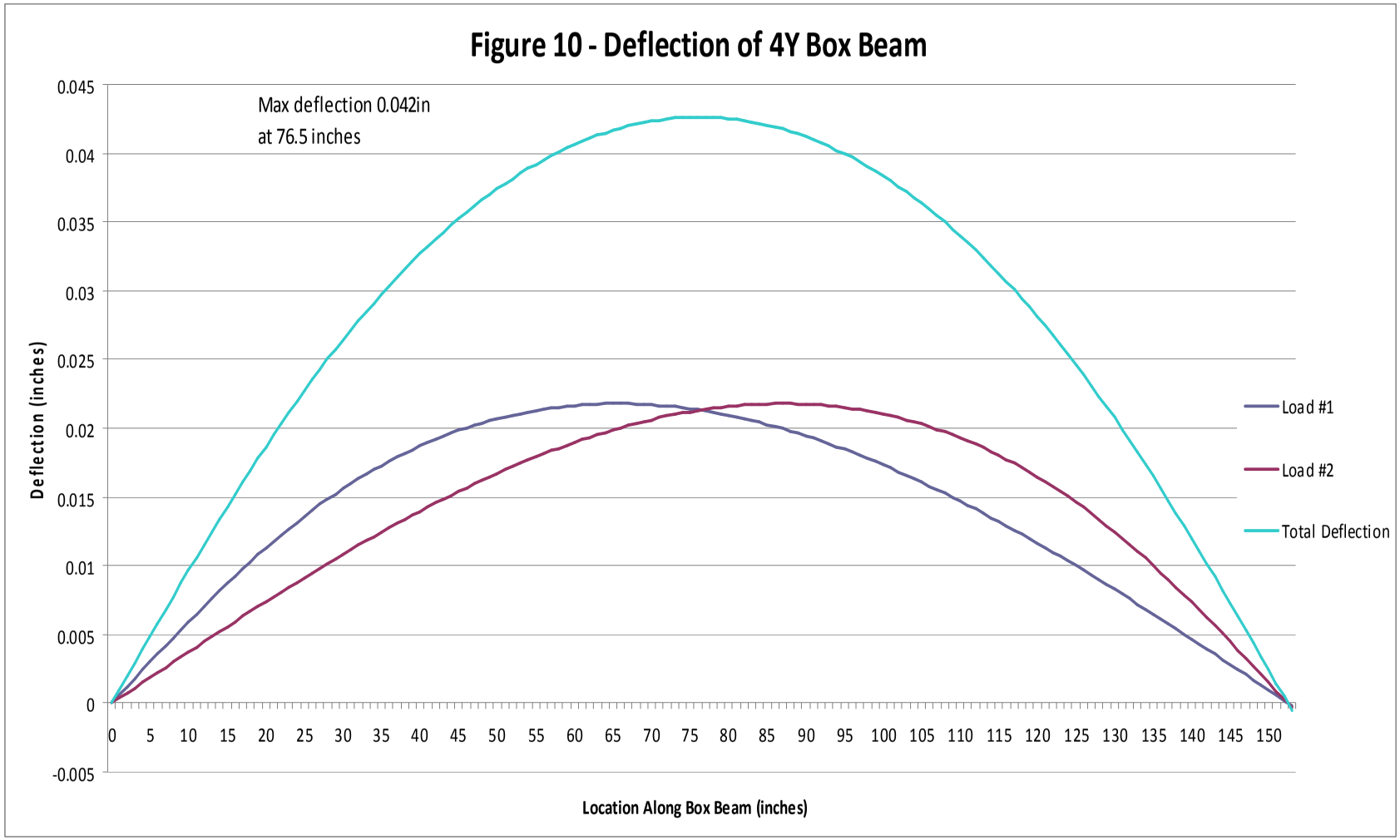
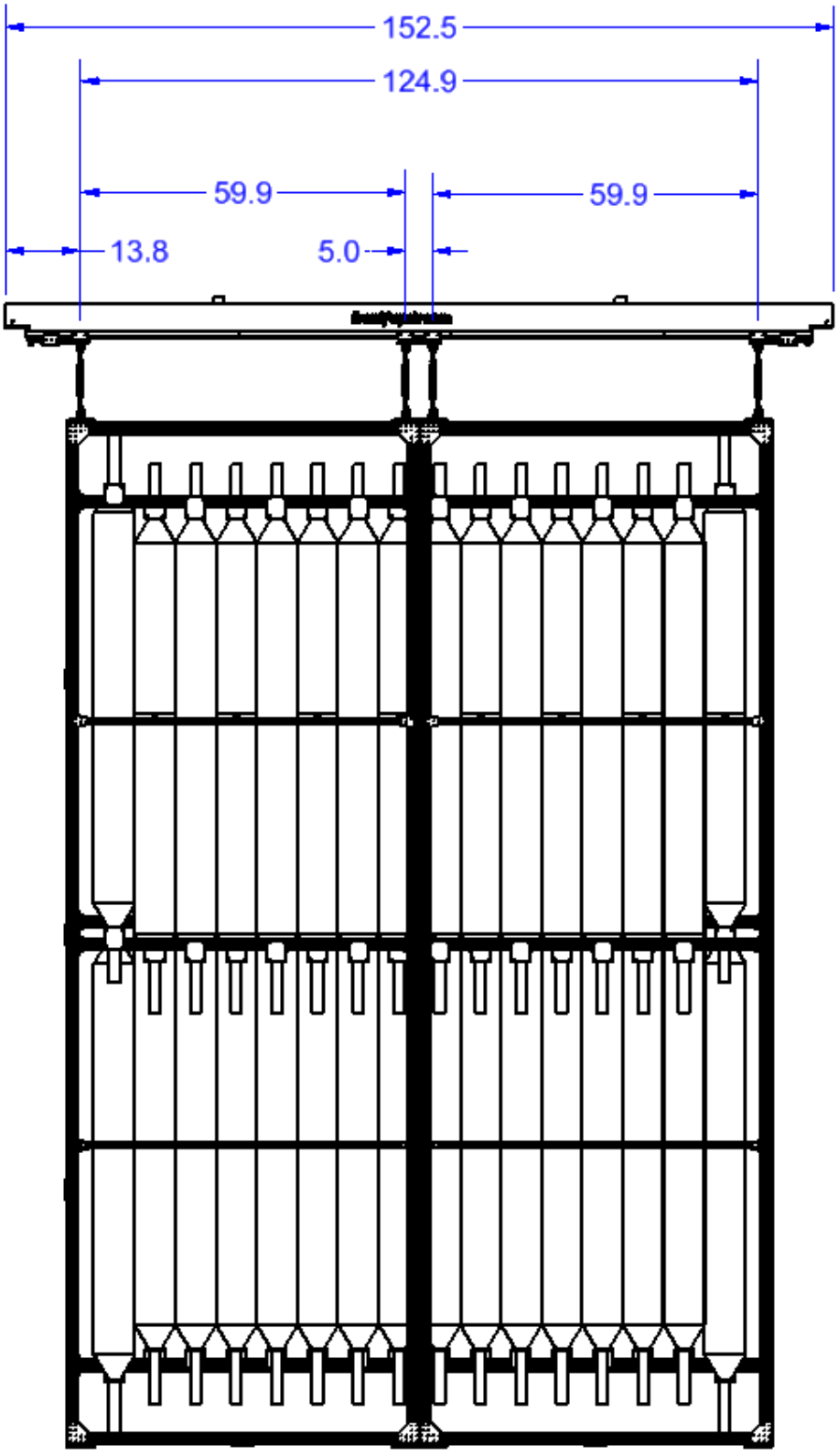
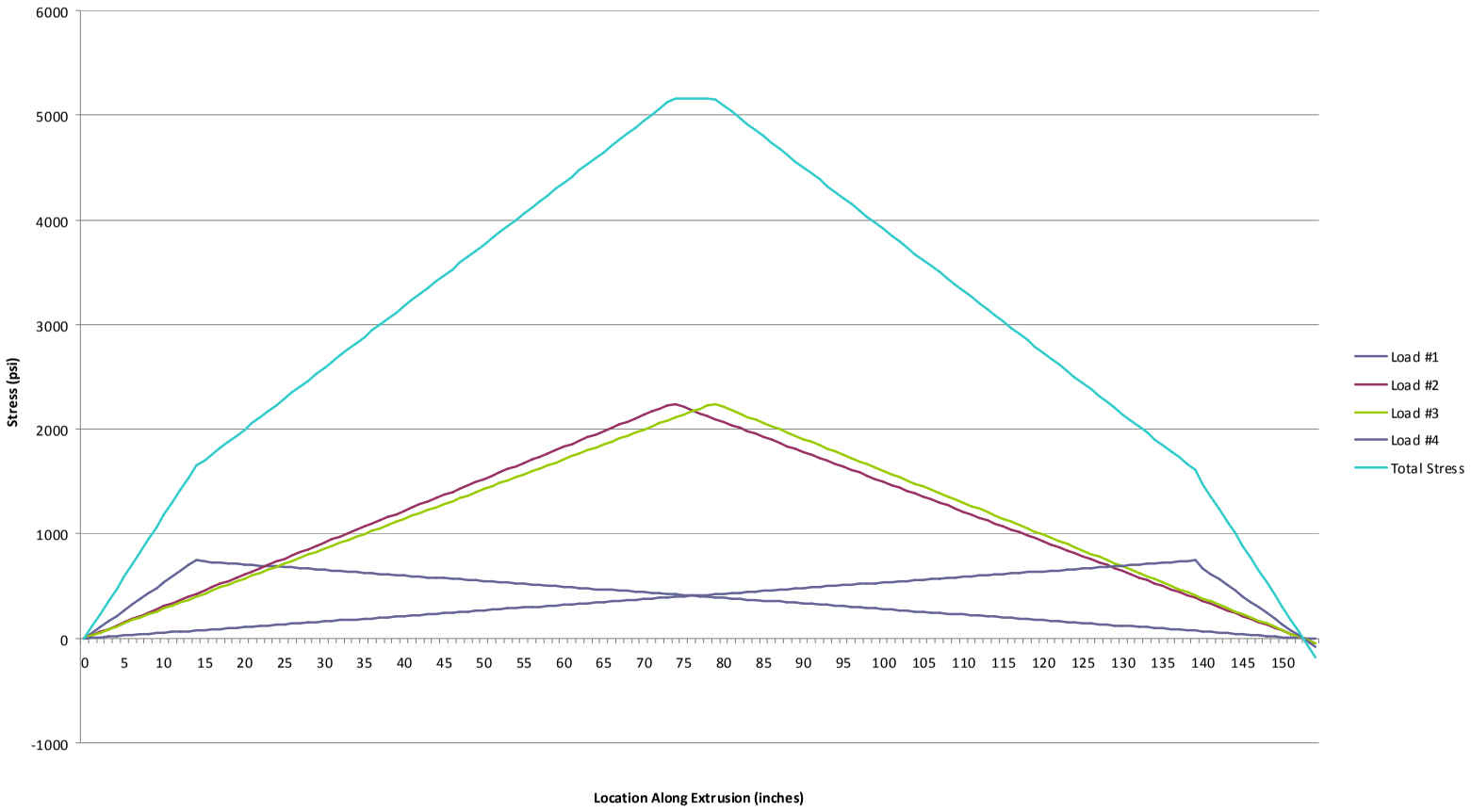


Figure 10 - Deflection of 4Y Box Beam
Max deflection 0.042in
at 76.5 inches
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
-0.005
Deflection (inches)
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150
Location Along Box Beam (inches)
Load #1
Load #2
Total Deflection



Figur 11

Figure 12 - Stress on Hodoscope 4X



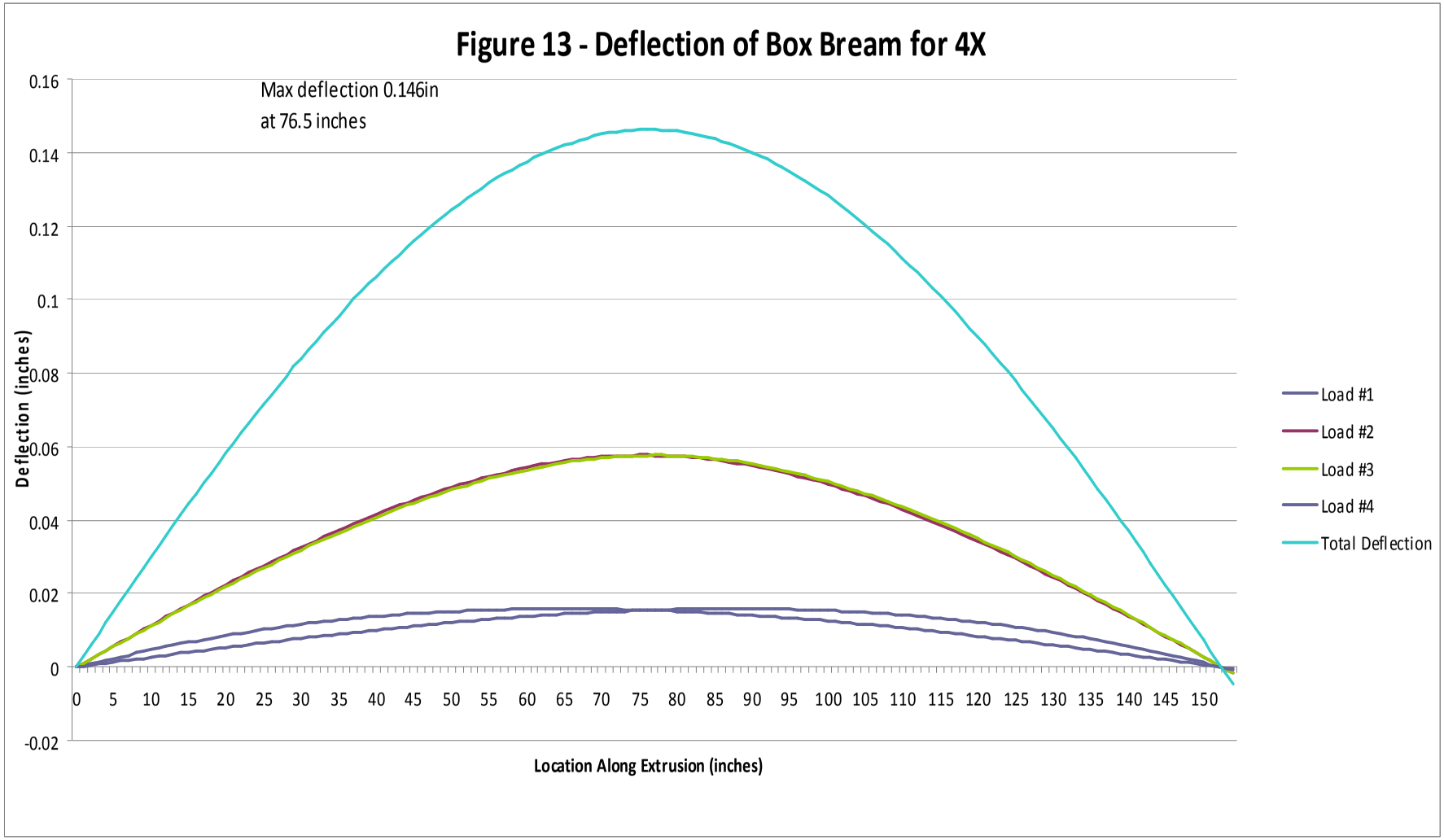


Figure 13 - Deflection of Box Bream for 4X
Max deflection 0.146in
at 76.5 inches
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
Deflection (inches)
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150
Location Along Extrusion (inches)
Load #1
Load #2
Load #3
Load #4
Total Deflection